

Compact and High Performance Dual-band Bandpass Filter using Resonator-embedded Scheme for WLANs

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Abstract. *A compact microstrip dual-band bandpass filter (DBBPF) with high selectivity and good suppression for wireless local area networks (WLANs) is proposed utilizing a novel embedded scheme resonator. Two passbands are produced by a pair of embedded half-wavelength meandered stepped-impedance resonator (MSIR) and a quad-wavelength short stub loaded stepped-impedance resonator (SIR) separately. The resonator is fed by folded T-shaped capacitive source-load coupling microstrip feed line, and four transmission zeros are obtained at both sides of the bands to improve selectivity and suppression. Simultaneously, the size of the filter is extremely compact because embedding half-wavelength MSIR only changes the interior configuration of quad-wavelength SIR. To validate the design method, the designed filter is fabricated and measured. Both simulated and measured results indicate that good transmission property has been achieved.*

Keywords

Dual-band bandpass filter (DBBPF), wireless local area networks (WLANs), stepped-impedance line (SIR), resonator-embedded scheme, folded T-shaped feed line.

1. Introduction

With the rapid development of modern wireless technologies, dual-band devices have been more and more attractive in global system for mobile communications (GSM), wireless code-division multiple-access (WCDMA), and especially in the newly developed wireless local area networks (WLANs) standards such as IEEE 802.11b/g (2.4/2.45 GHz) and IEEE 802.11a (5.15–5.825 GHz) specifications. Recently, compact size, high-performance and low cost dual band filter is in great demand for enhancing system performances. For requirement of application, dual-band bandpass filter has been widely studied in many papers [1-13]. In [1-3], dual-band filters were implemented by combination of two single band filters and each of these bands was designed separately. Unfortunately, these filters occupy double area of a single band filter and they are not

suitable for compact systems. Besides, dual band filters also can be designed by using two or more resonators. Filters based on SIRs [4-6] and simple patch resonator with slit in the center [7], [8] are proposed. However, these methods cannot achieve high performances effectively. They always have disadvantages of bad insertion loss and large size. On the other hand, centrally loaded resonators, which exhibit property of dual-mode, also attract more attention for their application in obtaining dual band responses. In [9-13], DBBPFs based on stub-loaded resonator are proposed.

In many references, most of the aforementioned DBBPFs focus on the central frequencies of two pass bands only, and they ignore the bandwidths of the two bands. For example, the bandwidths of DBBPFs for WLANs are not broad enough to fit the specification at upper band [4], [7], [9], [10]. So, two DBBPFs must be designed to meet with the requirement of WLANs. At the same time, the rejection of these filters is not good enough for anti-interference. Therefore, it is hard to put these filters into practical applications.

In this paper, a DBBPF is presented by embedding MSIR in short stub loaded SIR. The lower passband is mainly affected by short stub loaded SIR and the higher passband is mainly affected by the embedding half-wavelength MSIR. Besides, two pairs of transmission zeros are introduced to improve selectivity and suppression. Additional, because embedding half-wavelength MSIR changes the interior configuration of quad-wavelength SIR only, the size of the fabricated filter is extremely compact. Experimental result shows that a DBBPF operates at 2.45/5.49 GHz with 3dB fractional bandwidths 4.5% and 15.8% respectively. The proposed filter can be used for WLANs effectively.

2. Analysis of SIR

To design a DBBPF using SIRs, the properties of SIR must be analyzed first. As shown in Fig. 1, the basic structure of half-wavelength SIR consists of two lines of different characteristic impedances Z_1 and Z_2 and electrical lengths θ_1 and θ_2 . It can be treated as two uniform cells (*cell A* and *cell B*). The resonance conditions can be ob-

tained from one of them since the half-wavelength SIR is symmetrical [14]. The impedance of the resonator can be calculated as expression:

$$Z_{in} = jZ_2 \frac{Z_1 \tan \theta_1 + Z_2 \tan \theta_2}{Z_2 - Z_1 \tan \theta_1 \tan \theta_2} \quad (1)$$

According to the above equation, the resonance appears when Z_{in} is infinite, namely the denominator is equal to zero. As a result, the following expression can be obtained as the resonance condition:

$$\frac{Z_2}{Z_1} = \tan \theta_1 \tan \theta_2 = R_z \quad (2)$$

where R_z is the impedance ratio. In expression (2), we can see that the resonance conditions are determined by θ_1 , θ_2 and R_z . It can adjust these three factors to obtain the resonance that we required, and a dual mode filter can be designed by using SIR.

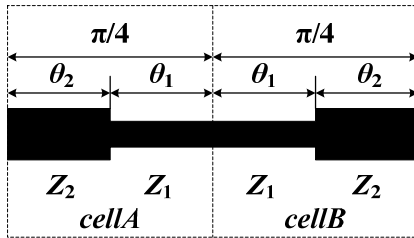


Fig. 1. Basic structure of the half-wavelength SIR.

The first spurious resonance occurs at

$$\tan \theta_{s1} = \infty \quad (3)$$

θ_{s1} is the electrical length for the first spurious frequency f_{s1} . In this paper, to design a good WLAN filter, the first spurious frequency must be avoided at 5.15-5.825 GHz as the lower passband designed.

3. Design of DBBPF

Fig. 2 shows the transformation process to design an embedded-scheme resonator for DBBPF. In Fig. 2(a), a quad-wavelength short stub loaded SIR is shown. To reduce its size, the SIR is folded as an open-loop. Additionally, the low impedance lines of quad-wavelength short stub loaded SIR are broad enough to provide area for a small resonator, which make it possible to embed a pair of small coupling resonators. So, we replace the low impedance lines with a pair of meandered SIRs, which is shown in Fig. 2 (b).

To achieve a high performance dual-band filter, it is necessary to introduce transmission zeros at both sides of the bands. Due to the existence of via hole, magnetic coupling takes up dominant position on the short stub loaded SIR shown in Fig. 2(a). On the other hand, as the embedded MSIR is folded as an open-loop, it has the maximum electric field density at the side with an open gap, and the

maximum magnetic field density at the opposite side. If the sides with the maximum magnetic field of two coupled resonators are proximately placed, the magnetic coupling can be obtained. Therefore, the coupling between the half wavelength SIR loops is also magnetic [15]. So, transmission zeros near the two pass bands can be generated by feeding microstrip feed line with capacitive source-load coupling, which because the counteraction between electric field and magnetic field. These transmission zeros have permits to improve selectivity and suppression of this filter.

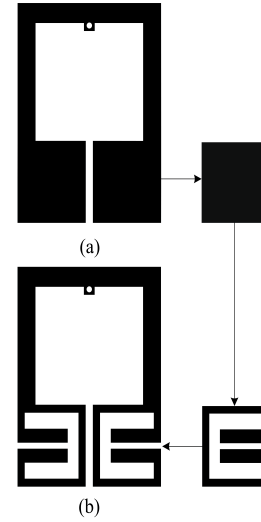


Fig. 2. Embedded-resonator DBBPF design scheme.

A filter proposed for WLANs is shown in Fig. 3. A set of parameters of it is given as follows: $W_0 = 2.8$ mm, $W_1 = 0.7$ mm, $W_2 = 0.4$ mm, $W_3 = 0.4$ mm, $W_4 = 1$ mm, $W_5 = 0.4$ mm, $W_6 = 5.9$ mm, $L_1 = 2.4$ mm, $L_2 = 3$ mm, $L_3 = 4.1$ mm, $L_4 = 1.5$ mm, $L_5 = 4.6$ mm, $L_6 = 6$ mm, $L_7 = 0.6$ mm, $G = 0.2$ mm, $G_1 = 0.3$ mm, $G_2 = 0.4$ mm, $G_3 = 0.4$ mm, $R = 0.15$ mm.

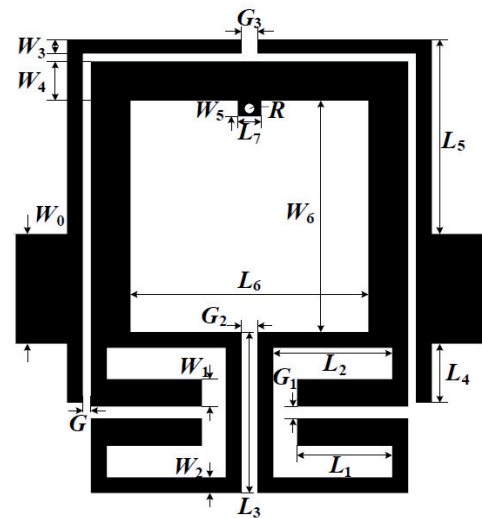


Fig. 3. Configuration of the proposed DBBPF.

In this structure, the stub length L_4 and gap width G can be adjusted to achieve a desired external quality factor of the proposed filter. The internal coupling of the filter

can be satisfied by tuning the parameter G_2 . The operating mechanism of dual band filter can be explained by the current distributions. As shown in Fig. 4, the surface current distributions at the resonance frequencies of 2.45 and 5.49 GHz simulated by CST are given respectively. It can be observed that a large surface current density is induced on short stub loaded SIR when the proposed filter operating at the lower band (2.45 GHz), whereas for the upper band excitations (5.49 GHz), the current distributions become more concentrated along the embedded half wavelength SIR rings.

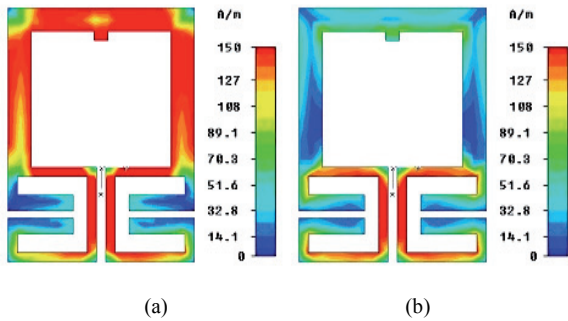


Fig. 4. Surface current distributions at 2.45 and 5.49 GHz for the proposed filter. (a) 2.45 GHz, (b) 5.49 GHz.

4. Simulated and Measured Results

To validate the characteristics, the proposed dual-band filter is fabricated and measured. A F4B-2 substrate with a relative dielectric constant of 2.65, a thickness of 1 mm and loss tangent of 0.002 has been used in this paper. A 50Ω microstrip feed line with a width of 2.8 mm is located at both of the input and output ports. Fig. 5 shows photograph of the fabricated dual-band filter.

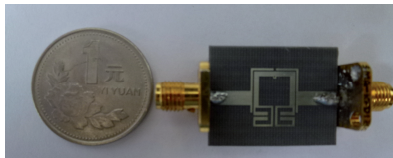


Fig. 5. Photograph of the fabricated dual-band filter.

Fig. 6 depicts the simulated and measured results of the proposed filter simultaneously. Here, Ansoft HFSS.10 is used for simulation and An Anritsu ME7808A vector network analyzer is used for measurement. The simulated/measured minimum insertion losses are 0.75 dB/1.3 dB at 2.45 GHz band and 0.48 dB/0.96 dB at 5.49 GHz band, and the simulated/measured minimum return losses are 20 dB/15 dB at 2.45 GHz band and 28.2 dB/24.3 dB at 5.49 GHz band. The measured 3dB bandwidths are of 4.5% and 15.8%. Two pairs of transmission zeros outside the passbands are located at 1.70 GHz, 2.78 GHz, 4.24 GHz and 6.65 GHz, which improve the out-of-band suppression and selectivity. In addition, group delay response is about 23.4 ns with a variation of 3 ns over the lower passband as shown in Fig. 7(a) and about

4.4 ns with a variation of 0.5 ns over the upper passband as shown in Fig. 7(b). As a conclusion, the distortion of the upper band is better than the lower one.

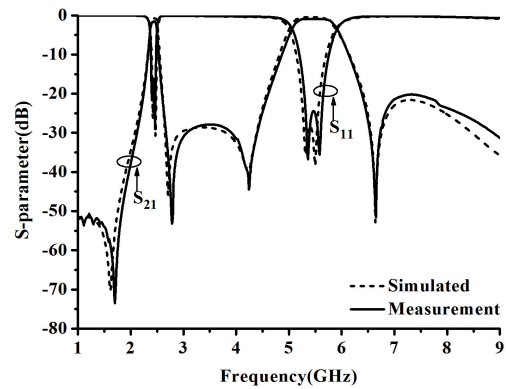
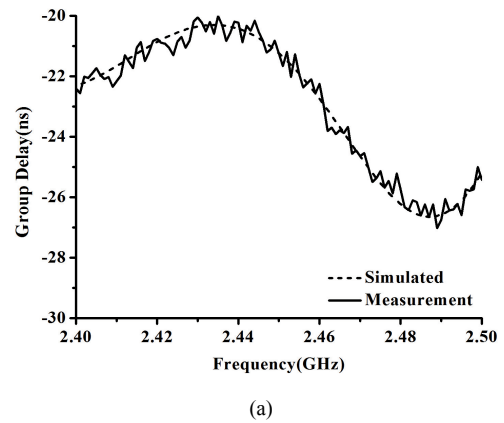
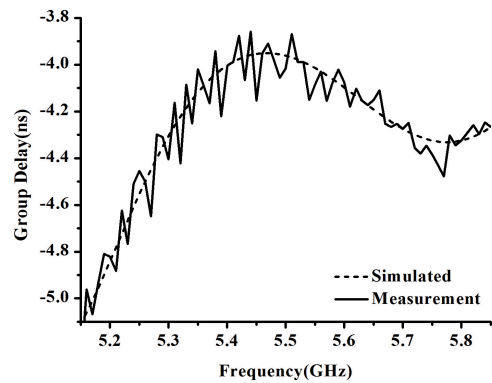


Fig. 6. Simulated and measured results for the proposed filter.



(a)



(b)

Fig. 7. Group delay for the passband: (a) Lower band, (b) upper band.

The size of proposed filter is $0.14 \lambda_g$ by $0.109 \lambda_g$, where λ_g is 82.9 mm, the 50Ω guided wavelength at the lower passband. In Tab. 1, the comparison of the developed filter with some typical filters for WLANs is summarized. It can be found that overall performances of the DBBPF in this paper are better than the referenced filters, especially in terms of the size.

	Filter size (without 50 Ω microstrip feed line)	Transmission zeros between passbands	Measured insertion loss in passbands	
			lower band	Higher band
This work	$0.14 \lambda_g$ by $0.109 \lambda_g$	2	1.3 dB	0.96 dB
Ref.4	$>0.178 \lambda_g$ by $0.148 \lambda_g$	1	1.6 dB	1.2 dB
Ref.7	$0.46 \lambda_g$ by $0.42 \lambda_g$	2	0.6 dB	1.4 dB
Ref.9	$0.144 \lambda_g$ by $0.118 \lambda_g$	0	1.7 dB	1.5 dB
Ref.10	$0.227 \lambda_g$ by $0.188 \lambda_g$	2	1.6 dB	2.2 dB

Tab. 1. Comparison with some typical DBBPFs for WLANs.

5. Conclusion

In this paper, a dual band filter designed by only one proposed embedded-scheme resonator was presented. Folded T-shaped line with capacitive source-load coupling is used for feeding, and multiple transmission zeros are created to improve the performances of proposed filter. To illustrate the method clearly, the design process of embedded-scheme is given in this paper. A good quality DBBPF operating at 2.45 and 5.49 GHz for WLANs is well designed and fabricated. It is apparently that the measured results of the filter agree with the simulated ones. The size of proposed filter only occupies the area of $0.14 \lambda_g$ by $0.109 \lambda_g$, which is smaller than those filters given in references. The designed filter exhibits good performances for WLAN applications in terms of the selectivity, the bandwidth, the suppression and compactness.

Acknowledgements

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